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Review

Extending body and imagination: moving to move

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Abstract

This article discusses a range of interactive body-worn systems and devices for performance, play, rehabilitation and disability or altered-ability support. The systems combine experimental and off-the-shelf technologies to arrive at outcomes that require and inspire extended physical and expressive engagement, and afford a range of different learning opportunities. Notions of extended bodies, shared augmented environments, magical thinking and play are examined for their poetic valence, as well as for therapeutic potential. Much of the work is in its early stages. Several scenarios of use are outlined for each of the devices, and relevance to ArtAbilitation proposed. The aim is to generate collaborative interest and inform development.

Keywords: body-worn technologies; extension; physical engagement; play; self-expression; self-knowledge.

Introduction

The research discussed represents a systematic examination of how technological extension might poeticise experience through novel forms of physical engagement (1, 2). The original intentions of the investigation were 'to move the body through real and virtual extension' and thereby discover the poetic valence of the different approaches taken, as well as to blur boundaries between art and everyday life to discover situations where playful and poetic engagement might transform experience and improve outcomes. From the outset, where therapeutic applications for the devices suggested themselves, these are described, along with the characteristics of each of the different systems.

Expertise brought to bear on the different projects includes fine art, materials sciences and engineering, as well wearable technologies. The desire has been to encourage people to explore and extend the range of movement they have available to them, by providing unusual and engaging opportunities to move in extended, self-directed ways. By extending the body outwards, prompting the wearer to move, participant's awareness seems, paradoxically, to extend inwards. Attention is drawn to qualities of movement, and this heightened awareness is often described as poetic.

The systems discussed are idiosyncratic, open systems for expressive engagement that encourage different qualities of attention. There is no right or wrong way to proceed, and no required or desired outcome. Participants are free to create their own dynamically evolving frameworks for use. This allows for the generation of activities pitched at an appropriate or desired level. It also allows the difficulty of the activity to be increased or decreased at the participant's will. Outcomes are uncontrolled, and benchmarks set by participants, so the devices can be used by novices, experts and elite movers, as well as by people with different challenges and unconventional abilities, with or without the guidance of a mentor, trainer, therapist or health practitioner. The systems are intended to be physically and imaginatively engaging, for a range of contexts and abilities.

Methods

The suite of body-worn systems for physically engaged and expressive interaction are discussed in detail in the following section. The development process in each case has been an iterative, reflective process guided by Art and Design ideation techniques and intuitive processes. At the outset, basic prototypes were constructed. The prototypes were then developed in negotiation with a broad a range of participants, including highly skilled performing artists and people with different physical challenges and abilities. By covering extreme case scenarios (3), the desire is to better understand the limitations and affordances of the different approaches, as well to make devices that work for different bodies, interests and potentials. As targeted applications are identified, prototypes can then be developed into more robust systems for specific use.

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Measuring the moving body outside the laboratory

Measuring the body in movement is a major challenge for physically engaging interactive systems. The research discussed here makes use of high level off-the-shelf technologies such as Arduino (Arduino is an open source electronics prototyping platform: http://www.arduino.cc/) and ZigBee (ZigBee is a low-cost, low-power, wireless mesh networking standard: http://www.zigbee.org/), as well as a custom textile sensor that has been developed at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to measure elbow and wrist flexion, allowing for the relatively unconstrained movement and degrees of freedom in these parts of the body (4). The sensor has been tested and compares favourably to the Vicon motion tracking system (Vicon Motion Systems are a registered trademark of Vicon: http://www.vicon.com/) – considered an industry "gold standard" for motion tracking (ibid). In this work it has been adapted for use to measure flexion at the waist.

The advantage of using body-based sensors as opposed to a camera vision system such as Vicon is that body-based sensing is not restricted to the point of view of a camera (or cameras), the data can be followed in real time and, most importantly, testing can take place in any environment, including outdoors, as installation of hardware or support systems is not required. Taking testing and evaluation out of the laboratory allows use in situations and contexts that are comfortable and/or familiar for the participant. This results in a more inclusive evaluative procedure, as well as data that relates more closely to real life.

Evaluation

Evaluation has been characterised by shared experience. The desire has been to create a common language as a prelude to more formal qualification. Observation, open interview and subjective reporting of participant experience have been integral to the process. Researcher participation has also played an important role. As participants attempt to translate extra-discursive (non-observational) subjective experiences into language, these reports must also be compared. Having direct personal experience of using the interfaces seems to enhance the researchers' ability to ask relevant questions, to gain clarification of what participants might mean. The common experiences act as a support for the development of an appropriate articulation of events.

Early reporting

Outcomes that suggest a range of applications are reported, without yet having fully tested each hypothesis. The devices tested to date are clearly prototypes, yet participants have consistently engaged with them for extended periods of time, have expressed a desire to 'have one for themselves' or to share them with friends or children. They also have repeatedly suggested a broad range of applications in the area of disability (most commonly where they have personal experience with people with the disability in question). I therefore feel that reporting at this stage is appropriate. It is helpful to understand and shape how the work might move forward in an ArtAbilitation context, as well as to engage with this community to consider the benefits of working in openly structured ways, making open systems for physically engaged creative engagement.

Results

The suite of devices described in this section cover a range of augmenting approaches: extending through technology with light; simple and complex sound; graphic output; and literal, physical, tangible extension of the core of the body, horizontally. Soft prosthetic extensions (that do not contain technology) are also described: exploratory devices that represent yet-to-be imagined technologies that bring participants' awareness to their bodies, their desires and their dreams of future body-worn technologies.

Extending through technology

Four different approaches are presented. Although subtly different in impact and affordances, they all show that open systems for physically engaged creative expression provide platforms for learning in, through and about the body. The value and opportunities relevant to ArtAbilitation are discussed on a case-by-case basis.

hipDisk

hipDisk extends the body horizontally to exploit changing relationships between hip and torso to actuate simple tones. It thus gives the wearer's body musical capabilities. Two horizontal disks are worn around the torso – one above the waist, the other below the waist, at hip height. A total of 12 soft binary switches are spread evenly around the periphery of two disks. As the wearer tilts their hip and torso in opposition, and the disks touch, different notes can be triggered. *hipDisk* requires people to extend their core body, often in exaggerated ways, to make sound. Several tonal arrangements and scales have been tested: a chromatic scale, a major scale and a minor scale. Different participants have different preferences, thus currently all three options are made available. The interface brings to light idiosyncrasies in posture and flexibility. It also provides information about individual body-centric learning preferences, as people instinctively look for the most comfortable way to learn how the device behaves – through visual supports; physically: proprioceptively and kinaesthetically, as well as with tactile support from others; through sound; or observation. Some participants even use spatial orientation, although the interface is self-contained and centred on the body, thus no matter which direction the wearer faces the behaviour of the device is consistent.

Moving the hips in extended and powerfully intentional ways is not a common activity. It can be highly pleasurable. In the case of *hipDisk*, it also looks very strange. We do not

normally view the body extended horizontally. We also do not normally undertake activities that have a disproportionate relationship between effort and outcome. The *hipDisk* can require an inordinate amount of effort to play certain notes (this differs for each person, and is related to posture and flexibility), yet the outcome is a reedy, almost tinny, unrefined tone. There is nothing sophisticated or graceful about the *hipDisk* in any traditional sense, yet participant response has been overwhelmingly positive (5).

It has become apparent through presenting the failed attempts of a quartet of performers to master a tune wearing the *hipDisk*, that the humanity of the struggle to play the interface is incredibly endearing and encourages people to want to play the device themselves. Because it is seemingly impossible to succeed with the *hipDisk*, there is no threshold of success or failure. Use of the device is, therefore, democratised. The interface is fun and provides a challenge that is engaging, entertaining and novel, and it can be used in a complex way as each participant desires. When people wear the *hipDisk*, they work together or alone, they mimic other participants or do opposing experiments. They rarely remove the device in under half an hour, and when they do they seem highly energised and to date always desire to describe their experience and discuss how their use compares to that of other people. *hipDisk* provides a novel opportunity for self-expression, exploration and knowledge generation through playfulness and social engagement. The therapeutic value of this seems clear for able-bodied participants – the device is fun and it connects people to their bodies and provides self-knowledge. I believe there would be similar benefits for people who are less physically able. Although *hipDisk* might not address particular physical pathologies, it could be useful for other types of pathologies where self-confidence and embodied engagement are an issue. It is also attached to the body in a very firm yet comfortable way, clasping the torso above and below the waist. This could be pleasurable for people who respond positively, and are calmed by pressure.

Gesture≈sound experiments

The *gesture≈sound experiments* extend the body with sound to mesh gestural/physical and sonic composition in such a way that sound production seems to be an inherent and unavoidable consequence of moving the body. The desire is to encourage people to explore through movement and sound, interdependently; and also to understand the nature of engagement when the physical interface is relatively discrete. The tested interface consists of Nintendo Wiimotes (Trademarks registered. Further info is available at http://www.nintendo.co.uk/NOE/en_GB/wii_54.html) bandaged to different parts of the body, sending sensor data to a computer running *Max* (a registered trademark of Cycling74. Further information is available at: http://cycling74.com/products/) to play sound patches developed in *Audiomulch* (an interactive music program created by Ross Bencina. Further information is available at http://www.audiomulch.com/). The sensors have been attached to forearms, shoulders, hips, upper and lower legs, spine and sternum. The different sound patches have been designed to encourage and support different types of movement exploration with each of the targeted body parts (6).

Gesture≈sound is free and unconstrained, in comparison to *hipDisk*. Any movement (of the Wiimotes) can be tracked, within the constraints of the different patches, and the sound is algorithmically generated, thus relationships between gesture and sound can be far more complex than the binary offerings of the *hipDisk*. The unconstrained nature of *gesture≈sound* opens up a free-form expressive space that can be used to encourage exploratory movement with targeted parts of the body. If language is, indeed, generated out of movement (7), increasing a person's capacity for movement expression could support greater ease with verbal expression, as well as other forms of communication. It has been suggested that *gesture≈sound* would be useful for people with spectrum disorders, in particular autism, where the children in question have inordinate amounts of energy and a tendency to obsess and make patterns. In its current form the sensors are worn, rather than integrated into garments, thus this may or may not be an issue – depending on whether the participant gains pleasure and comfort from physical pressure, is hypersensitive to touch or where their comfort levels lie between these extremes. Informal discussions with parents of children with autism suggest that developing the interface for their use would be welcome. (The open nature of all of the systems has been remarked upon in informal conversations with parents of children with autism. In each case they are eager for their child to have access. They suggest that the openness presents an opportunity for their child to engage in an exploratory manner, in a system that operates outside of language and has room for their idiosyncrasies.)

Light arrays

The *Light Arrays* extrude the body with light to magnify articulations, gestures and postures. They highlight how a person's movement impacts space physically and how the different parts of their bodies interact with each other and others in shared space. The system uses lasers and/or LED arrays, which, to date, have been attached to the limbs, the spine and the core of the body. By incorporating lights into garments and worn modular fabric supports, the *Light Arrays* prompt wearers to interact and engage, through the lights, with body position and movement as well with their dynamic position in space. Wearers report being inspired to move in new ways and to discover and explore their bodies through movement, in ways that differed from their usual methods, approaches and habits (8). Although the wearer cannot see the lights in their entirety, this has been reported to be inspiring, rather than frustrating.

The *Light Arrays* suggest several different applications. Extending out from the waist with lasers, for example, might be useful for participants with vestibular disorders. By observing the array of dots on the walls surrounding them, the participant would be able to identify if they are standing upright (in which case the dots would be aligned horizontally) or if and how they might be off balance (in which case the light array would be tilted). The system could also be used

to inspire people to engage their bodies through imaginative tasks, and thereby be more engaged to undertake physiotherapy. For example, a treatment for leg ulcers involves compression bandages and regular movement of the ankle to maintain circulation. If circulation is not maintained treatment fails, yet it is challenging to get people to regularly and randomly move their ankles over extended periods, thus success rates remain low. By attaching a laser to the base of the foot, the patient could be asked at regular intervals to draw objects, write lists or otherwise map out things that they are interested in or passionate about. Tasks could include: writing the names of their grandchildren; mapping out their favourite walk through town; the relationships between their friends; the plants in the garden; the tools in the shed, etc. Participants could also be asked to follow the contours of the room with the laser; or trace out different objects in the surrounding environment; to solve complex mathematical equations; to draw pictures or to write out musical scores. The role of the health practitioner would be to assist the patient in finding tasks that resonate for them emotionally. If the task resonates emotionally for a patient, they might be more likely to engage over an extended period. In the case of patients with leg ulcers, this enhanced engagement would lead to beneficial results in their healing process. A discussion of how the *Light Arrays* are being extended, and further relevance to ArtAbilitation, is provided in (9).

hipDrawing: graphic extension

The *hipDrawing* interface turns the wearer into a human, hip-controlled Etch-A-Sketch (a registered trademark of Ohio Art: http://www.etch-a-sketch.com) by transforming hip-movement data into two-dimensional (2D) graphics. The interface uses custom textile sensing technology (4) to measure change in relative tilt between the hip and torso. The data is sent wirelessly to a computer running Processing (an open source programming language and environment. Further information is available at: http://processing.org/), and is mapped from 3D to 2D and projected onto a screen as graphic traces in a Cartesian environment. A version is also being made to send the graphic output to a smart phone or PDA, eliminating the need for projector, laptop computer, as well as architecture to support the projection. The *hipDrawing* garment also incorporates an accelerometer so that shaking the body can be used to erase the drawing (just as shaking the Etch-A-Sketch screen erases the Etch-A-Sketch drawing). It is currently made for one participant, but a multi-user version is planned to examine social navigation and engagement. In the multi-user version, participants draw on a shared screen. If one person shakes their body (or is shaken), the entire drawing is erased and their 'line' goes to the bottom of the hierarchical structure. It will be used to examine how participants navigate shared space.

hipDrawing has a very clumsy mapping. As described above, the relatively unconstrained 3D movement of the body at the waist is mapped onto xy-coordinates. As a result, its use is sometimes anti-intuitive – moving the body can result in unexpected graphic output. To draw something specific requires an ongoing shift in attention between the actions and gestures of the body, and the resulting graphic output on the screen. This causes a quality of attention that is inhabitual, an intensity of focus that people would not normally turn to the body in movement. This intense scrutiny of hip gesture opens up new ways of seeing, thinking and generating knowledge about this part of the body. More intensely than the other devices in the suite of works described here, *hipDrawing* prompts a process of creating and reflecting on new modes and patterns of bodily experience, as facilitated by the interaction between body movement and the effects of the technology (10).

The clumsiness of the mapping also serves to democratise the technology in a similar way to the clumsy, gracelessness of the *hipDisk*. This results in a system that is highly accessible to people with varying abilities, as there is no 'right' way to succeed. Tasks can be designed for personal idiosyncrasies and desired challenge levels, and outcomes provide access to the inherent aesthetics of movements of all types. This could provide desirable experiences for people with a range of physical and communicative challenges, for self-knowledge, as well as for creative expression and playful physical engagement – see Gallagher (7) for an extended discussion of the interrelation of body schema and physical activity, and benefits of engaging in different types of movement that affect motility and postural schemas, as well as the role of vision in proprioception.

Summary

The works described demonstrate that extending the body mechanically, gesturally and sensorially can encourage people to move in extra-normal ways, and thus view and experience their bodies from perhaps hitherto unknown perspectives. This, in turn, opens up a free-form expressive space that provides a rich playground for self-expression, as well as surprising opportunities to observe how people learn in, through and about their bodies. It affords insight into how our bodies can move and what this feels like; individual body-centric learning preferences; and the idiosyncratic nature of personal, corporeal expressiveness.

Soft prosthetic extension: the OWL project

The *OWL project* operates somewhat differently from the works described above. Rather than providing an open system for physically engaged creative expression, the *OWL project* engages participants in co-creation and collaborative imagining of that which does not yet exist. There are two parts to the *OWL project*: interviews and workshops.

In the interviews, a series of body props, that do not contain technology, are used to bring the wearer's attention to the body in inhabitual ways. The devices are open and speculative, designed without a predefined function and tested as design 'probes' (11) to ascertain their functionality. As the interview progresses, each new device is incrementally stranger – the first two give and receive pressure, the next two destabilise by shifting the body off axis, and the third two are like

mutations that extend out from the body in subtle but unusual ways. Interviewees are asked simple questions such as: How does it feel? What is it? What does it do? And if it gave you magical powers, what kind of powers would they be? The aim is to create an emergent, imaginative space in which people might be able to conceptualise technologies that do not yet exist. The desire is to plumb people's willingness to imagine through the body in movement; discover what might happen if we let people use their embodied experience and imagination to assist in the creation of unknown technologies; and to bring the wearers' attention to their embodied(ness) to see if this brings them present to their inner state and encourages magical thinking. To date, interviews have been conducted in Europe, Australia, North America and Japan. The interviews are formalised, yet open. The objects are evocative, and the interview format is designed to slow down the moment of perception, 'making strange' that moment of considering an object as a worn presence within each personal space (12).

The workshops are a little different. Rather than beginning with devices, participants are asked to choose a desire (13), to decide where in their body it might live, then to build an exploratory object from recycled materials that somehow embodies their dreams, in relation to this 'embodied' desire that gives them magical powers. Arthur C. Clarke writes that "any sufficient advanced technology is indistinguishable from magic" (14). The *OWL project* interrogates this idea directly.

Creative thinking across cultures and communities

The geographical, cultural and socioeconomic reach of the *OWL project* is giving us the opportunity to explore cultural differences and similarities expressed as creative thinking. Many of the outcomes are surprising. For example, in one instance, two people from radically different cultures, and political and socioeconomic backgrounds used identical words to describe what one of the devices does. In another example, a participant who was interviewed in July 2009 reported in June 2010 that he continues to have lasting changes as a result of the things that were brought to mind during the interview process. His relationship to reading shifted, and he found himself examining why he did many things the way he did, and subsequently transformed many aspects of his life. He claims to be much happier as a direct result of the insights he gained during the interview. With regard to one device, the quality of response has differed wildly, yet the valence has been the same. Although it is difficult to draw clear conclusions from these outcomes, without exception, the experience of the *OWL project* has been reported as being unusual and bringing the attention to the body in new, different and deeply thoughtful ways (15). We would like to see if this process might contribute in positive ways to how disabled people view and imagine through their bodies, as well as the type of agency they imagine they might have with regard to the conceptualisation and development of technologies that are relevant to them and are yet to be imagined. The first workshop with a disabled group will take place in Sydney in November 2011, within the context of the 11th Participatory Design Conference, Art of Participation workshop and exhibition series.

Discussion

Body-worn devices are normally tightly coupled with the body – unable to be repositioned, picked up or put down. They support different types of engagement than non-wearable systems as well as different types of physical experiences and knowing. Yet they may also present challenges for a less able-bodied participant. Putting a garment on may be difficult, and different types of movement and form factors, if not allowed for in the design of a garment, could compromise sensor precision, and thereby coherency of data. For this reason, it is essential to include 'otherly-abled' and atypically bodied participants in development processes. Doing so will support the broad range of people, bodies and modes of expression in the community, rather than restricting use and research outcomes to body-typical users.

The openness of systems and devices described here allow for the generation of activities, pitched at an appropriate level, to target specific outcomes. This is ideally suited to people with unconventional physical and expressive abilities. Practitioners could work with a participant to design an individual program, and also guide them as they invent their own games. As benchmarks are set on an individual, case-by-case basis, the devices could be used by people with different challenges and unconventional abilities to achieve a range of results at a speed or pace appropriate to each individual. Tasks could also be designed for personal idiosyncrasies. Outcomes provide access to the inherent aesthetics of different movements, as well as novel ways of seeing and experiencing the body. Those with low- or unconventionally functioning bodies could be encouraged to use the neglected parts of their body willingly, inspired by the expressive potential of the different extensions as their attention shifts between how moving feels and aesthetically refined results of their actions. Doing so could allay further muscular degeneration through extended engagement and/or lead to greater physical control. Highly positive results have been seen, for example, when dance is practiced by people with cerebral palsy (16). The systems described here provide alternatives to dance, allowing participants to engage expressively through their bodies in a multitude of ways.

Gibson (17) writes of perception leading to an awareness of affordances. If we consider that perception is a skilled activity (18), turning attention to and through the body by augmenting perception can lead to opportunities to learn new somatic techniques and increase specific skills and/or range of movement. Noë argues that "perceiving is something we do" (19), and perceptual awareness depends on the perceiver having "sensorimotor knowledge" – an implicit understanding of the way sensory stimulation varies with movement. Experimenting with novel experiences in and through the body seems to provide insight into the body's capacities and affordances. Participants could thereby develop their sensorimotor knowledge and skills, and shift their perception of their bodies' affordances, as well as perception in general.

Conclusion

The devices described here encourage people to explore and move in playful ways. They open up a free-form expressive space that affords insight into how our bodies can move and what this feels like; individual body-centric learning preferences; and the idiosyncratic nature of personal, corporeal expressiveness. They engage the mind, emotions and feelings with the body, in all its dynamic capacity that might have been hitherto ignored. The openness of the systems, coupled with the, at times, clumsy nature of the interaction they afford, brings people to new ways of seeing and experiencing the body. There is no "right" way of performing tasks with these systems, there is simply an open environment in which to explore, and in which to find each individual's preferred approach. This is supportive of different levels of ability and prowess. It also supports the design of activities to achieve particular outcomes that acknowledge and support the individual's strengths, preferences and needs. For all of these reasons, as well as the playfully engaging nature of the devices, I believe them to be ideally suited to disabled or physically and communicatively challenged individuals. My expertise is not in disability research, thus my suppositions in this area risk being naïve. Nonetheless, I see many applications for this work in disability and rehabilitation. The scenarios of use I am proposing include artistic applications for performance and play; engaging rehabilitation patients, physically, through their imaginations – having patients draw or write things through their bodies (10, 20). I also see broad application with people who have underdeveloped or damaged proprioceptive abilities and/or communicative issues. Extended physical exploration seems to lead to greater self-knowledge, which in turn can lead to extended abilities, enhanced empathic relationships with the self and thereby greater ease in communication (7). I believe this to be of value in many abilitation contexts.

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